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Design ways to communicate efficiently in a complex matrix test program	Ares 1-X Communication	Robert Ess	The fact is that you can't educate everyone on your team because your team within NASA is never just a team of people that you see. There also is the matrix support team back at the institutions and directorates. Those are the ones that are really going to have a lot of influence on what happens and so it's a challenge, it's a daily challenge, every day.	Ares 1-X Clip: Better is the Enemy of Good Enough	21
Realize the challenges with virtual teaming	Ares 1-X Virtual team dynamics	Vince Bilardo	Operating with those five centers in that virtual project environment was very much a challenge.	Ares 1-X Clip: The Importance of Co-location	21

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The project manager must be present at the center of gravity	Ares 1-X Project management - Co-location	Robert Ess	As project managers consider where the center gravity of the project is at any stage and find a way to get close to that. Forge relationships with those people and I think you'll have a much better understanding of what's really happening with your project if you do it that way.	Ares 1-X: Clip: The Importance of Co-location	21
Co-locate design engineering in launch-site integration	Ares 1-X Project management - Co-location	Stephan Davis	Most of us moved to the Cape for the last eight or nine months. That made a huge difference as we stepped through the integration and testing	Ares 1-X Clip: The Importance of Co-location	21
Keep work and family life in a healthy balance in these fast-paced projects.	Ares 1-X Workforce Stress & Health	Carol Scott	We tend to jump into these special projects and run them at a sprint race. Don't forget about your family and friends.	Ares 1-X Clip: The Human Element	21

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Pay attention to your employees in fast-paced projects and watch for stress buildup.	Ares 1-X Workforce Stress & Health	Jon Cowart	As managers in particular you have to look and see how folks are doing and pay particular attention to them during stressful times.	Ares 1-X Clip: The Human Element	21
Change people out in demanding programs to avoid over-pushing people.	Ares 1-X Workforce Stress & Health	Jonathan Cruz	With such a fast-paced, demanding program it's important not to over-push people and to be able to be flexible enough to change out people even just temporarily when needed.	Ares 1-X Clip: The Human Element	21
Communicate and discuss changes in standard roles and responsibilities with all stakeholders, especially external ones	Ares 1-X Organizational roles and responsibilities	Ed Mango	If you're going to have different, non-standard roles and responsibilities for major decision-makers, such as the launch director, start discussing that early on, especially with external stakeholders such as the engineering and safety tech authority.	Ares 1-X Clip: Roles and Responsibilities	21

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Staff the SE&I function fully	Ares 1-X Systems Engineering	Jon Cowart	System Engineering & Integration (SE&I) has a huge role. They have to be a real technical authority on the whole rocket. Staff them properly and give them a little more resources than they think they need.	Ares 1-X Clip: Roles and Responsibilities	21
Function as a single integrated team	Ares 1-X Project Management - Organization	Robert Ess	We banned the use of phrases like level 2, level 3, level 4. We were all part of an integrated team.	Ares 1-X Clip: Organizational Structure	21
Maintain a focus on communication and information sharing	Ares 1-X Project Management - Communication	Dan Mullane	The Mission Manager always stressed that we were one team, breaking down barriers and silos of information that can exist between levels and centers. If you want to move fast in an efficient way, communication flow and the sharing of information is extremely important and while Ares I-X wasn't perfect, I thought it was the best example that I have experienced in my 20 year NASA career.	Ares 1-X Clip: Safety and Mission Assurance	21

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Recognize the team building and team training dimension of flight test projects	Ares 1-X Project Management - Teambuilding	Dan Dumbacher	One of the main take-ways was that the analyst, designers, system integrators and the operators all learned what needed to be done on this flight test, and what didn't need to be done, in addition to the technical take-away by getting the data we needed to inform the development program for Ares and Constellation.	Ares 1-X Clip: Senior Leadership Part Two	21
Don't glance over minority opinions, lean on experts	Minority opinion, expert knowledge	Mike Fowler	And so my lesson learned from that is that while you should be listening to all of the minority opinions, you should also respect the expert's opinions on what is and isn't a valid concern. So I think that it's good to listen to other people. It's good to listen to, you know often times there's negative information or questions that are asked that are good to, that no one had thought about. But there are also times that there are things that should not be pursued as vigorously or spending as much time trying to pursue	KBR 11938 Clip: Context; Minority Opinion-Time marker: 0:00	21
Build confidence through technical conversations	People, Trust and Confidence	Alvaro Rodriguez	One of the big lessons I learned through going through the repair project and seeing it to success, was the value we had in the team members and learning how to divvy up the roles. We had to learn to, especially for mission support, how do we work with each other and how do we trust and rely on each other to all come together to ultimately make a recommendation to the project. A lot	KBR 11934 Clip Context; On-Orbit Reinforced Carbon-Carbon Repair	21

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			of that was building trust with each other in terms of our technical discussions. Even personal relationships that we had built up; those were invaluable.		
Design interfaces as common as possible	Personnel training Smart simple design = reduced failure opportunities in use	Scott Parazynski	Crew training is critical when you have new tasks that require new tools or processes that are outside the normal training requirements. Overall the less design complexity and process complexity is involved the fewer opportunities for failure will be down the road during operation.	11934 – on orbit RCC repair – crew training	21
Assess organizational leadership and staffing risk as well as technical, cost, and schedule	SLWT Project - Risk Management	Bryan O'Conner	There is a lot of risk talk you can do on the technical matters and on the performance versus safety, but the organizational approach is equally important. There is a human side to this. Is this going to be too much for this project manager to handle? Does this project manager have access to the right support from his host center.	Super Lightweight Tank (SLWT) Case Study Exercise 1: Risk Identification; video clip/transcript	22

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Value independent assessment and peer review	SLWT Project - Reviews and Independent Assessment	Bryan O'Conner	My memory says we had 50 or 60 if you add them all up from start to finish, independent and peer reviews of one sort or another throughout this project. This team was not embarrassed to talk about their issues, claim their lack of understanding and asks for help. I think that is pretty key to success in a project.	SLWT Exercise 1: Risk Identification; video clip/transcript	22
Take no shortcuts in development testing	SLWT Project - Verification testing	Mike Pessin	When you start a program, you need to do your due diligence and understand what you're getting into - do the the advanced technology development. Give the people the right test hardware, give them a chance to do the proper testing. If you try and do that on a shoe string, it's going to come back and bite you!	SLWT Exercise 2: Materials - Risk Mitigation; video clip/transcript	22
Establish and maintain a documented, controlled project baseline	SLWT Project - Project management	Brewster Shaw	I highly recommend that we have an equivalent to 07700 to tell you how to execute the program and it talks about risk management specifically, having that to fall back on was an excellent way to manage a big, complex, high-risk program like Space Shuttle	SLWT Exercise 4: Design Verification Risks; video clip/transcript	22

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Defend against requirements creep	SLWT Project - Project Management - requirements management	Brewster Shaw	Requirements management, baseline configuration management, are extremely important. Requirements creep is a living thing in our programs and if you don't keep it under control, it'll ruin your program.	SLWT Exercise 4: Design Verification Risks; video clip/transcript	22
Plan and manage, to the extent possible, with margin	SLWT Project - Project management	Parker Counts	We set an internal goal of 8,000 pounds – so we were striving to do 8,000. Now we succeeded with 7,500 plus; but at least we started with some margins, so we had some ability to redirect in some areas.	SLWT Exercise 6: S&MA Risk Mitigation Planning; video clip/transcript	22
Build-in budget reserves	SLWT Project - Project management	Parker Counts	We had a development budget of about $132 million. We were able to complete the project and still have $20 million in reserve.	SLWT Exercise 6: S&MA Risk Mitigation Planning; video clip/transcript	22

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Secure dual suppliers for critical elements/material	SLWT Project - Supply Chain management	N/A; Report	Reynolds Aluminum was the sole supplier of Al-Li 2195 but was not the original inventor, and initially was not able to reproduce the material. The project qualified Alcoa as another qualified supplier of Al-Li 2195	SLWT Lessons Learned (3 of 4); PPT	22
Apply the mantra that better is the enemy of good enough on a test project	Ares 1-X Design test and analysis	Robert Ess	If you can do another analysis or if you can do another test, we typically try and do that. That's our culture. But for a flight test and its okay if there's a possibility that it won't work, so better is the enemy of good enough really was the mantra that we tried to instill upon the managers and the lower level managers	Ares 1-X Clip: Better is the Enemy of Good Enough	22
Tailor risk management processes consistent with a flight test project	Ares 1-X Risk Management	Bruce Askins	As far as actual risk for our project, we kept the scoring approach the same as regular programs. So a lot of our risk ended up scoring higher than what you probably would expect for just a test, project.	Ares 1-X Clip: Better is the Enemy of Good Enough	22

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Incorporate design engineering in launch-site integration	Ares 1-X Project management - Co-location	Vince Bilardo	From an engineering perspective, there is just no shortcut for having a presence at the launch site, being close to the hardware and having the ability to inspect it with your very own eyes and with the team, the stakeholders who are involved in trying to resolve that issue	Ares 1-X: Clip: The Importance of Co-location	22
Select common electronic tools (Requirements, RM, CM, EVM, schedule)	Ares 1-X Project Management tools	Bruce Askins	Carefully select the proper configuration management tool and include some good training for everyone upfront.	Ares 1-X Clip: Information Technology	22
Move toward paperless processing of hardware.	Ares 1-X Project Management tools	Jeff Campbell	Paperless processing of hardware provides for a quicker way to change, close out and process control procedures.	Ares 1-X Clip: Information Technology	22

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Manage scope and requirements creep.	Ares 1-X Project Management	Vince Bilardo	Two-thirds of our cost growth was driven externally by the increase in scope and the creep in requirements. It's not easy and it takes a lot of very disciplined and focused attentive work and appropriate systems and processes to very carefully define your configuration and then to hold it.	Ares 1-X Clip: Plan Then Do	22
Maintain contractual responsibility, even though you operate as a badge-less team.	Ares 1-X Contract Management	Ron Unger	It's nice to all say you're going to throw your badges on the table when you walk in and you're all one big happy family, but you still have to maintain that level of contractual responsibility as well	Ares 1-X Clip: Roles and Responsibilities	22
Recognize that NASA Standards are guidelines - tailor them appropriately for a given project	Ares 1-X Requirements Management	Jon Cowart	All those NASA standards out there, they are guidelines. If they don't make sense, talk about them and agree to not do them. I don't care what size your project is, don't feel like you have to follow those rules/standards. Be smart.	Ares 1-X Clip They are Guidelines, not Requirements	22

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Consider concurrent engineering when facing a compressed schedule project	Ares 1-X Design, Development, Test & Integration	Ron Unger	Build a mindset early on within the project team that given the compressed schedule, we are going to do concurrent engineering (requirements development, design, fabrication, stacking, testing).	Ares 1-X Clip: Schedule Management	22
Manage to schedule when schedule is "King"	Ares 1-X Schedule-driven, risk informed Project Management	Robert Ess	We made decisions to stay on schedule. After a while that's infectious and people realize that we're doing this. It not when we get around to it or when the analysis is done, but it's like, we're really doing this.	Ares 1-X Clip: Schedule Management	22
Stay on schedule by making timely risk-informed decisions	Ares 1-X Schedule-driven, risk informed Project Management	Jon Cowart	When we were "not ready" for a decision that had to be made to stay on schedule, we would talk about the situation very openly so that we could identify the real problems and the project manager can make a risk-informed decision.	Ares 1-X Clip: Schedule Management	22

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Empower the SE&I function with overall budget and schedule authority	Ares 1-X Project Management - Organization	Jeff Campbell	We had a flat org structure and delegation to the IPTs, you have to have a strong SE&I function up front, and this function needs to have the authority to maintain the overall project schedule and budget, what in a traditional program is called level 2.	Ares 1-X Clip: Organizational Structure	22
Minimize your number of control boards	Ares 1-X Project Management - Organization	Robert Ess	We decided to operate with one control board for most of the project, since most of the same people would be at any subordinate boards anyway. At the end we only created subordinate boards for instrumentation and floor processing to handle day-to-day near real time decision making.	Ares 1-X Clip: Organizational Structure	22
Empower the SE&I managers to manage	Ares 1-X Project Management - Organization	Robert Ess	A flat org chart becomes wide, and you have to deal with many interfaces. SE&I managed those interfaces, not as integrators, facilitators or coordinators, but as empowered managers. Don't just make them book managers. These are mini-project managers.	Ares 1-X Clip: Organizational Structure	22

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Select one schedule tool and make sure everyone is using it	Ares 1-X Project Management tools	John Howell	On this project the schedule was king. Take time initially to pick a good scheduling tool and mandate that everyone use it. We used Primavera.	Ares 1-X Clip: Business Operations	22
Control cost by managing the schedule	Ares 1-X Project Management tools	John Howell	Schedule is money. Provide training to technical managers to understand that and give them the tools to manage cost and schedule.	Ares 1-X Clip: Business Operations	22
Use top-down and bottoms-up risk identification methods.	Ares 1-X Safety and Risk Management	Dan Mullane	Our systematic identifying of safety and mission success risks consisted of a top-down fault tree analysis and a bottoms-up FMEA/CIL study. That worked well.	Ares 1-X Clip: Safety and Mission Assurance	22

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Employ multiple, mutually supportive risk management approaches	Ares 1-X Safety and Risk Management	Dan Mullane	We used the risk management system, in addition to the fault trees, hazards and FMEA/CILS for risks for which it is not clear yet how we will manage them. We can't write things in a hazard report that are not defined yet.	Ares 1-X Clip: Safety and Mission Assurance	22
Make no compromises on integrated test and verification	Ares 1-X Safety and Risk Management	Dan Mullane	Towards the end there was some pressure to forego some verification activities in order to keep the launch date. We had some spirited discussions. We ended up completing all verifications without slipping the launch date. This meant that many folks worked long hours. We got the job done and I think that helped pave the way to success.	Ares 1-X Clip: Safety and Mission Assurance	22
Implement rigorous risk management and quality assurance processes	Ares 1-X Safety and Risk Management	Dan Mullane	I always go back to two basic areas—you have to make sure you have a strong analytical function to make sure that you are being very systematic in identifying sources of risk. The other function that I think you have to have is a very good quality assurance program to make sure that all of the analyses that you are doing are valid because the hardware that we are going to fly is actually the same as the design that you analyze. And whenever it's not, make sure it's understood and get a proper engineering assessment.	Ares 1-X Clip: Safety and Mission Assurance	22

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Centralize the SE&I function and give it a project-wide scope	Ares 1-X Project Management - Organization	Marshall Smith	We reformulated the project after one year and put SE&I in a single place with more of a project focus rather than a vehicle or ground focus. This helped the project along.	Ares 1-X Clip: Systems Engineering and Integration	22
Implement a "Lean" approach to rapid early development flight test activities	Ares 1-X Project Management - Organization	Jeff Hanley	We understood that we needed to really be successful with I-X, we needed to stand up a leaner, small team, much smaller than the full program team to really work in parallel so that we could really make this early flight test happen, but yet not have it sideline or derail the main line activity of formulating Ares I and Orion.	Ares 1-X Clip: Senior Leadership Part One	22
Utilize available "Lean" training to prepare rapid development teams	Ares 1-X Project Management - Organization	Jeff Hanley	I had asked the, at the time, deputy project manager for Ares, Dan Dumbacher, to do a lean event, if you will, a lean six sigma activity, to look at how we were working together to make Ares I-X happen.	Ares 1-X Clip:: Senior Leadership Part One	22

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Empower rapid prototype development team management	Ares 1-X Project Management - Organization	Jeff Hanley	It became pretty clear that we needed to establish a truly independent team and that I needed to give them the freedom to move as rapidly as they possibly could. In other words, putting Bob Ess in the leadership position and empowering him to make decisions at his level without a tremendous amount of care and feeding, if you will, of the main line program.	Ares 1-X Clip: Senior Leadership Part One	22
Expect rapid prototype development to place schedule first	Ares 1-X Project Management - Schedule	Jeff Hanley	A lean team that is focused on staying on schedule needs to make decisions to moving. You can't dither and get into analysis paralysis. It means that the senior leaders on the team need to make tough choices and they're not going to have a warm tummy feeling with every choice that they make.	Ares 1-X Clip: Senior Leadership Part One	22
Recognize the advantages of rapid prototype development to complement traditional human space flight DDT&E	Ares 1-X Project Management - Organization	Jeff Hanley	A development program can go down two paths What we've been used to in human space flight is a path of doing rigorous ground testing before we commit to a flight test, and that is the way much of the Constellation plan had been formulated. What Ares I-X showed us is that there is another strategic path of incremental flight testing, or incremental build-up in capability, through flight testing as an alternative means to reach certification.	Ares 1-X Clip: Senior Leadership Part One	22

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Consider advantages of a flat organization in DDT&E activities	Ares 1-X Project Management - Organization	Jeff Hanley	Whenever you have a vertically oriented organization with many levels to it, there's a tax you pay in what would be a fixed cost that is going to stay with you. A flat organization avoids those costs.	Ares 1-X Clip: Senior Leadership Part One	22
Recognize that project organizational structure should be re-evaluated at each life-cycle phase.	Ares 1-X Project Management - Organization	Jeff Hanley	One of the conversations senior management should have with the project manager and program manager and that the program manager should have with his project managers and so forth is whether we organized properly for the next phase? E.g., design integration in phase B is very different in nature than conceptual work in early phase A.	Ares 1-X Clip: Senior Leadership Part One	22
Consider ways in which ARES I-X project demonstrated new approaches for hardware development	Ares 1-X Project Management - Organization	Dan Dumbacher	One of the big reasons for doing Ares I-X was to be able to get a development flight test off, get some data into the design process quickly, but it also had the secondary benefit of demonstrating to a large part of our work force that not everything had to be operated like shuttle, like a human space-flight program.	Ares 1-X Clip: Senior Leadership Part Two	22

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Limit the amount of contract change activity	Contract changes effecting Program overall objectives	Chris Calfee	The proposed cost for the DART project—and Orbital Sciences was the prime contractor—was approximately 50 million. Half of that cost was for the launch services, and that was essentially a fixed cost for the Pegasus launch vehicle. The other 25 million was for the design, development, test of the spacecraft itself which had the key sensors to provide the navigational technology to get to Mobilecom, which was our target spacecraft. At the end of the day, the total cost of the DART project ended up about 110 million, and there were various reasons why we ended up there.	DART Video Case Study: Page 18. 0:00 Cost Section	22
Establish reasonable milestones that will support adequate testing	Schedule pressures and reasonable targets	Chris Calfee	Schedule pressure is going to be a part of every project that we do at NASA. It's been a part of every project I've ever worked on, and I expect it will be a part of every project I ever work on at NASA. There was one difference for DART: we had a target spacecraft called Mobilecom. It was a retired Department of Defense satellite that was basically given to Orbital. It had completed its mission; it obviously had a limited life. The original target launch date was April 2004. That had slipped a little bit, we were in the fall of 2004, and we were worried about Mobilecom even being there.	DART Video Case Study: Page 19 TIME 0:00 Schedule Section	22

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Ensure adequate staffing and increase as necessary with changes in baseline	Organizational Priority	Chris Calfee	Push back a little bit more early-on.. I was told, or directed, that I was to have a fixed amount of project office personal, and it was four.	DART Video Case Study: Page 20 Section: Other constraints Time 0:51	22
Set a verification baseline in line with risk posture early on	Systems Engineering Design Verification	Jim Snoody	In the beginning the verification approach was using a very similarity approach very heavily weighted toward similarity and analysis with not a full recognition of in space environments, a launch vehicle and the complication of the technology being very low with very little hardware in the loop, system-type test, so as we evolved out of the CDR.	DART Video Case Study: Page 21, Section Risk Posture and Verification Approach Time: 1:37	22
Engineer upfront	Peer review disposition of risk	Jim Snoody	DART ended up with 300 plus related to critical design review, ended up with six components that were failed and ended up in a band aid approach of trying to do system engineering so you spent all your time on DART trying to fix all the system engineering adequacies and you really didn't have time to think about the broader context and actually trying to figure out how to make it better, it was more one band aid after another.	DART Video Case Study: Section: Risk Posture and Verification P2 0:00	22

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Test Like you fly	Systems Engineering Design Verification	Jim Lomas	The SURI GPS receiver when it got on orbit for the first time in the DART mission it saw more satellites than it had ever seen before in any terrestrial application or any testing. The software inside the SURI didn't really know how to handle this very well and it caused a slight hiccup in the navigation state that the SURI was putting out. This caused a navigation state error which was the original cause for the filter, the GN&C navigation filter to reset. When that happens we take the solution from the SURI and use it as a starting point and then start trying to navigate.	DART Video Case Study: Page 32, Section: Rendez 0:08	22
Set up regular communication channels between design teams	Dispositioning all non-conformances	Jim Lomas	The second problem that the SURI had was an embedded velocity bias which was documented by the company, but not very well communicated between the various design teams.	DART Video Case Study: Page 32, Section: Rendez 0:48	22
Divide productions teams from enhancement teams	Organizing by project phase	Parker Counts	It was ideal to separate the production team (which was allowed to focus on supplying the LWT for continuing SSP operations) from the development team (which could then concentrate on SLWT) under one ET Project Manager, so that each team was not competing for the same resources.	SLWT Clip: Lessons Learned (4 of 4)	22

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Go back and review risks and assess how risks may have changed with time	Risk Management / ECLSS	Kirk Shireman	The key is continually going back and looking at those risks, even the ones that are not your number one risk to see if did I understand them correctly, have they grown over time, is our understanding of those changed, has other factors in the environment changed that would change my overall risk assessment, and where I would deploy my resources?	ISS Video Dashboard Shireman Clip 3, 44:40 - end	22
Test, Test, and Test	Design / ECLSS	Robyn Gatens	we learned things on orbit that maybe if we had tested more on the ground we would of uncovered on the ground. So test, test, test – I know I'm not the only one that ever says that.	ISS Video Dashboard Robyn Gatens Clip 8	22
Discover and expose undocumented assumptions	People / Communication / Operations	Mark Geyer	So I think how that how you apply that to things like testing and even analysis is that we need to be real clear on assumptions, on input variables, for example on loads, and even on factors of safety, on conservatism, because we definitely come at that in different ways. We each have our own biases about what we have experienced in the past. It is important to penetrate to that next level to ensure that you are integrated—whether it is an integrated analysis or an integrated test—that there aren't hidden things or gap.	ISS Video Dashboard Mark Geyer Clip 4 (all - esp 5:30 - end)	22

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Fly as fast as you can	DD&T / Design / Test / Risk Management / People	Mark Geyer	So you make a choice: fly something early, it's not the perfect design yet but you're going to learn a ton about the design and you're going to be able to focus the team, you're going to actually learn a bunch about how to not just the design but about the processes, processes, and even the contract and everything else and it shows that you're moving forward.	ISS Video Dashboard Mark Geyer Clip 6 (all)	22
Locate the reliability, maintenance, and logistics function within the design organization	Design / Logistics / Reliability	Anthony Butina and William Robbins	The recommendation would be is to have your logistics people in that design organization and in the engineering organization as early as you can so that they can do the things that they need to do so we could maintain the station more effectively.	ISS Video Dashboard Anthony Butina Clip 2	22
Conduct an integrated logistics support analysis	Design / Logistics / Reliability	William Robbins - Anthony Butina	LSA, Logistics Supportability Analysis, is a body of activities aimed at identifying what the resources are going to be needed in order to support the hardware as well as identifying the basics of crew operator tasks, how to do it, the parts that will be needed, the tools that will be needed.	ISS Video Dashboard William Robbins Clip 3 also Anthony Butina Clip 3	22

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Design for maintainability - 100 screws! Are you kidding	Design / Logistics / Reliability / Operations	Anthony Butina	. So there's a treadmill and that treadmill base has 100 screws around it in order to get to a motor that is embedded inside. The time it takes for a crew member to get 100 screws off to get into that is overkill. You just don't need to have that. ..... that three pound motor took a couple of hours to replace, not just because of the screws, but how it was embedded inside of that treadmill.	Anthony Butina Clip 4	22
Design for storage and trash management	Design / Logistics / Reliability / Operations	William Robbins	You have to have a detailed operational concept that considers, not only everything that is coming up that the crew is using, but what is the crew going to be using. How much consumables are there? What volume do the consumables take up? And, do those trades of onboard stowage and transportation options	ISS Video Dashboard William Robbins Clip 4	22
Consider the trade-off between reliability, maintenance, and supportability	Design / Logistics / Reliability / Operations	William Robbins	The more reliable the hardware is, the less resources you would need in order to maintain the hardware. There's a cost tradeoff with that in the design phase in that in trying to make the hardware more reliable you're increasing cost during the design and development phase with the expectation that you'll be able to reduce support costs	ISS Video Dashboard William Robbins Clip 5	22

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Implement commonality to reduce spare inventory (mass and volume)	Design / Commonality / Logistics	William Robbins	Commonality can be a big payoff, but it's very difficult to get a design team or a project to accept commonality requirements because they feel that it restricts their designer's ability to be innovative and they've got a point, but the payoff with commonality is that if you have common fixtures, common fasteners, common connectors, common parts, you reduce your support resources.	ISS Video Dashboard William Robbins Clip 7	22
Use Common Specifications	Commonality reduces the potential for error	Warren Woodworth	There is potential for process escapes or process errors, using one application in the wrong situations, in other words using a specification for one vendor and an application for another vendor, so it promotes the opportunity for errors. Commonality will eliminate a lot of that.	KBR 5046 Commonality (Indentificaiton of Risk)Time marker: 02:00	22
Reduce cost with commonality	Use aerospace or commercial standards to limit cost	Warren Woodworth	One thing that drives cost is having a unique design, having unique hardware, unique specifications, multiple specifications, unique materials... All this drives cost and it drives schedule, so the thing to strive for is commonality.	KBR 5046 CommonalityClip: Indentificaiton of RiskTime marker: 0:11	22

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Match as-built to drawing Configuration	Reduce mismatched parts with current drawings	Ed Statham	It is really important that you maintain an as-built database that is accurate, and that your as-designed be verified against the as-built, and probably released via a change order before you actually incorporate it into the new design.	KBR 5048Clip: Identification of RiskTime marker: 04:11	22
Prevent assembly operations surprises	Verification of as designed to as-built prior to new enigneering	Ed Statham	By closely maintaining your as-built configuration, and by checking your as-designed against that as-built configuration before you include the new engineering into the planning, you will avoid unnecessary surprises, schedule delays, and cost, by understanding completely what is required to go do a job prior to beginning.	KBR 5048Clip: Mitigation of Risk Time marker: 01:47	22
Unburden your configuration management	Use of non critical parts should be tracked wisely	Ed Statham	be smart about what you choose to track in your configuration management system. Track the things that are important to track, but don't track things that are not critical and otherwise don't require tracking.	KBR 5049 Cumbersome Pedigree Maintenance Clip: Mitigation of Risk Time marker: 02:38	22

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Fully Qualify Large Mechnical Systems	Verification	David McCann	For a large complex mechanical system like this you've got to perform a major qualification of the hardware; test as you fly. SARJ was originally designed to be tested that way; over the years as the program developed and cost constraints came along the determination was we would perform proto-flight testing of the two SARJs and that there wouldn't be a major qualification test performed on the SARJ.	KBR - 11825 Solar Alpha Rotary Joint (SARJ) Vibrations Pose Risk to ISS Power and Operations	22
Verify each mate-demate for all electrical connection	Assembly and checkout procedures Quality assuranceElectrical connections	Ron Welch	Often on complex setups, after a connection mate is made, connectors will become covered by other connectors or equipment in future assembly steps. Each mate or demate should have a one-on-one verification and be documented by the QA individual who personally witnessed the activity. This is extremely important and has the highest consequence for final mates prior to launch.	1363 Unverified Mating/Demating of Flight Connectors	22
Consider commercial off the shelf equipment for cost effective short lead time parts	Cost savings	Ben Greene	As the requirements were defined more, we realized that we could actually use commercial off-the-shelf equipment as the dispensing mechanism. At first it made the engineers uncomfortable since they are not part of the development of the hardware but in the end it was a cost effective and inexpensive way of accomplishing the task.	11934 – on orbit RCC repair – COTS Hardware	22

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Balance the right amount of analysis and testing to verify a design	Design and Requirement verification	Ben Greene	Too much time was spent trying to analyze one of the design options when in fact it was easy to test. Testing ended up being the method we used to verify the design option as viable but we spent a lot of extra time and resources on analysis that wasn't necessary in the beginning.	11934 – on orbit RCC repair – Verification planning: analysis vs testing	22
Challenge requirements. Challenge requirements. Challenge requirements.	Requirements	Lora Bailey	One the most important take aways from this experience, is kind of a repeat of many of my other projects, is that you do not blindly accept requirements that are given. You challenge them to begin with and fight and argue over them and hash them out as early as possible but also you don't give up on challenging them over the course of the project because the requirements are what can either drive you into the ground or drive you to success.	KBR 11938 Clip: Context; Key Remarks for the Future-Time marker: 0:00	22
Increase design safety factors when there is higher technical uncertainty.	SLWT Project - Design	N/A; Report	Due to questions about the fidelity of analysis, the goodness of the modeling, synergistic effects and the applicability of component testing data, we increased the safety factor to 2.0 and required independent analysis.	SLWT Exercise 4: 4.1 Introduce Higher Design Safety Factors; PPT	23

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Consider a Skunk Works approach when facing technology challenges	SLWT Project - Design & Development	Mike Pessin	And we managed this like a Skunk Works. This technique gives you a certain amount of risk because you don't get the multiple levels of review, but it gives you a virtually immediate response; and if you have the right people – and you've got to make sure you get the right people involved – it gives you a very efficient and streamlined program.	SLWT Exercise 5: Production Verification Risks; video clip/transcript	23
Solicit manufacturing practitioners experience and knowledge in solving tough design problems	SLWT Project - Problem solving in design	Bryan O'Conner	The project manager and his senior folks did not limit their brainstorming to themselves. Invite enough people from enough levels to participate in that. Sometimes you get the best answer by going to the floor and talking to the folks with the wrench in their hand and the torch in their mitt that are actually doing the job.	SLWT Four Important Take-Aways; video clip/transcript	23
Expect that heritage hardware will require the same integration level of effort as new flight hardware	Ares 1-X Heritage Hardware	Robert Ess	With heritage hardware, the physical integration and technical integration is as much work as if you started off from scratch and sometimes it's more work.	ARES 1-X Clip: Caution! Heritage Systems	23

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Expect that heritage hardware will require the same system-level verification as new flight hardware	Ares 1-X Heritage Hardware	Jon Cowart	Heritage is great, I recommend you go use it, but make sure you plan up front that down the road it's going to require from you some extra verification and certification time.	ARES 1-X Clip: Caution! Heritage Systems	23
Check heritage hardware drawings in case something changed in the interim.	Ares 1-X Heritage Hardware	Mike Stelzer	Don't trust the drawings of heritage hardware. Do those additional surveys to verify that your drawings- your models- are accurate and up to date in case something changed in the interim.	ARES 1-X Clip: Caution! Heritage Systems	23
Evaluate the end-to-end (design to launch) impact of heritage hardware before deciding on the use.	Ares 1-X Heritage Hardware	Robert Ess	If you think through the integrated end to end from design all the way to launch day impacts of a heritage change then you can understand whether it's really a good trade for you or not.	ARES 1-X Clip: Caution! Heritage Systems	23

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Design with integration and operability in mind	Ares 1-X Design and Integration	Jim Bolton	Infusing operability early makes a huge difference later. Include design engineers visiting KSC and ground ops people visiting design centers.	Ares 1-X Clip: Operability is Not an Afterthought	23
Test integrated avionics and anomaly conditions in a flight-like simulator lab.	Ares 1-X Design verification testing	Kevin Flynn	Use an integrated avionics simulation lab that truly has flight-like hardware, meaning having the same form, fit, and function as the flight boxes, and test all the functions possible. Especially testing things like anomaly condition is worth its weight in gold.	Ares 1-X Clip: Test Like You Fly, Fly Like You Test	23
Except to run loads and environments analysis up to the time of launch	Ares 1-X Design, Development & Test	Marshall Smith	Any time you build a new vehicle you're going to be doing loads and environments until the time you launch and after. I'm very convinced that this is never going to get better. It's always going to be uncertain. People are always going to be running loads. You're always just going to be saying, well, what if we did this, what if we did that. You've got to understand it, you've got to accept, and you need to set people's expectations so they don't freak out about it.	Ares 1-X Clip: Systems Engineering and Integration	23

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Recognize that flight test project design verification may differ in complexity from other types of missions	Ares 1-X Design verification testing	Marshall Smith	Doing verification is different for a fast moving one-of-a-kind vehicle development program than for operational environments. The former includes product verification where you actually check each part, whereas the latter uses just spot checks. The ARES 1-X project had people from both those cultures. Some of us had to learn to trust the processes and people and to not check everything on this one-of-a-kind vehicle.	Ares 1-X Clip: Systems Engineering and Integration	23
Test, Test, and Test	Ares 1-X Design verification testing	Marshall Smith	A flight test does not only solves the problems you think you're going to have, but it tells you about a lot of unknowns. You find out things you didn't expect. I highly recommend that you set up a series of test programs, each building on the next, similar to what we did in the past on Mercury, Gemini and Apollo. They had it right and that's the right way to go.	Ares 1-X Clip: Systems Engineering and Integration	23
Employ the latest (ARES I-X) updated acoustical environment prediction models	Ares 1-X Design Modeling	Marshall Smith	This test showed that we under-predicted the vibro-accoustic sound pressure levels for some places by a factor of three or four. This is not ARES 1-X specific but geometry specific. This allowed us to update our models, which now can be used for other vehicles as well.	Ares 1-X Clip: Systems Engineering and Integration	23

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Recognize the need to address triboelectrifcation risks and requirements	Ares 1-X Requirements Management	Jeff Spaulding	ARES 1-X was not treated or tested for triboelectrification, so we could not fly through any clouds above the minus 10 degrees Celsius level. This was a cost tradeoff decision that ended up delaying the launch one day.	Ares 1-X Clip: Triboelectrification	23
Early flight test is important to program growth and stability	Ares 1-X Project Management - Stability	Jeff Hanley	Senior management saw the technical value of 1-X, but also from a team perspective it was good getting an early flight test success.	Ares 1-X Clip: Senior Leadership Part One	23
Early flight test experience will inform "main line" development project structure	Ares 1-X Project Management - Organization	Jeff Hanley	what Ares I-X taught us is that we could treat the main line program very differently once we got past PDR, we could organizationally lean it out, flatten it, and get the team focused on flight tests, i.e. be test-centric.	Ares 1-X Clip: Senior Leadership Part One	23

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Review and renew ones understanding of data underlying any critical design model.	Systems Engineering Design Verification	Robert Manning JPL	The validation process didn't go back far enough into the past to look to ensure that we did the right thing from the original data. We were shocked; and, well, the good news [is] we caught it in time for the MER project.	KBR 1599 Common Mode (Model error) Failures in Technology Clip: 3:47 + 1:42	23
Verify that your model is valid for the application scenario.	Systems Engineering Design Verification	Rodney Rocha	There's always the opportunity or mis-opportunity to misuse a critical math model and fall into a pitfall of misuse, a flawed recommendation, an inaccurate statement about the usage of such math models.	KBR 11939 Application of Models in Design Verification and Safety Critical Decision Making first & last clip	23
Identify assumptions and uncertainties in using any model and build in margin as necessary.	Uncertainty in the space environmental models	Robert Manning JPL	As a system engineer, you need to be cognizant of the uncertainties in the environment that is being specified for you by environmental specialists, and if you have the ability to do it, you can hedge your bets by adding complexity and systems to try to deal with unexpected environmental conditions or conditions that may be worse than the specified environment that the experts have predicted. Because it turns out you're asking them a very difficult question, and when they give you an answer, you have to be aware of the fact that they may not be certain that that answer is correct.	KBR 1339 High Level of Uncertainty (Environmental Model)second clip	23

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Always perform an integrated test for critical systems - always.	ISS integration testing in a cost constrained environment	Stephanie Sowards	Using risk-based analysis to determine if we should conduct integrated test is a nice idea and it looks good on paper. However, given the complexity and the tightly coupled configurations of elements that span geographical and international boundaries that could result in catastrophic outcomes, the right thing to do is to always perform the actual integrated test. MEIT was designed to test mechanical, data, electrical, fluids every subsystem across those elements.	KBR 10440 ISS: Multi-Element Integration Testing (MEIT)second clip	23
Always perform an integrated test - known unknowns will emerge.	ISS integration testing in a cost constrained environment	Timothy R. Honeycutt	So these types of problems, we learned from them as far as finding them on the ground, resolving them prior to launching into orbit. If we would have had these types of problems on orbit, we would have had major cost and schedule delays. It would have caused increased safety issues for the crew. We could have had a loss of mission objectives and loss of flight hardware. It would have driven unplanned EVAs. So for future programs I would take all of this information under consideration from what we learned from MEIT not only that we need to look at what type of integrated testing we need at the launch site but also the planning that it takes to put one of these tests together providing all the correct GSE, the right personnel, the right involvement of other organizations and companies, down to the manufacturers level. To plan that up front is a great cost savings as well as to catch these problems that we find and resolve on the ground prior to getting in orbit. So some specific lessons from MEIT,	KBR 10440 ISS: Multi-Element Integration Testing (MEIT)last clip	23

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			one is the fact that we do know that we will come across unknowns when we integrate hardware together. There is no way of understanding all of the scenarios involved with large-scale integration of space hardware until you put the actual hardware together. You can simulate that, you can emulate that to the best that you can but there are some unknowns that you will come across when you actually perform that final integration.		
We must understand COPV failure modes.	Composite Overwrap Pressure Vessels (COPVs) in service now (SSP, ISS, spacecraft, EELVs) and will be used in future space systems (CxP, Lunar)	Multiple Subject Matter Experts	They are integrated throughout all of our vehicles. They are also integrated throughout our international partner's vehicles. Right now we are getting ready to inspect the AMS vessels which we have in our international partner's vehicles and also our payloads. Anything that is trying to save weight, we will put a composite pressure vessel in that application. We must understand the failure modes and be able to mitigate the failure causes so that we have a safe and reliable vessel.	KBR 7084 Composite Overwrap Pressure Vessel Safety Hazards First clip: Intro & background	23
Start and end with the same risk posture	Categorizing risk posture for program classification	Chris Calfee	DART was proposed and accepted as a high risk, low cost project. What came with that should have been a high threshold for risk and a reasonable amount of acceptance that there could be a failure here—it was a flight demonstration. So decisions were made early-on with that in mind, with those assumptions firmly in place and thought to be understood by management. As time evolved—and really it wasn't an evolution that it changed, it was like it flipped overnight—	DART Video Case Study: Page 21, Risk Posture and Verification 0:06	23

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			DART suddenly went from a ‘high risk, low cost’ to a ‘can’t fail, low cost’ project.		
Reduce Margins Carefully	Margin reductions represent increased risk	Mike Pessin	There are often places were margins can be reduced while maintaining the required FoS. There always represent areas of optimization, built is should be remembered that any form of margin reduction increases overall risk	SLWT Clip: Lessons Learned (4 of 4)	23
Be Flexible	TRL Levels may need back up plans	William Yuknis	I think the number one thing when encountering new technology, especially with a great unknown, the best thing that you can do in my opinion, is to be flexible. In other words be prepared to change the course and have a backup plan ready to go. In others word, we call it the "Plan B".	KBR 11397Parallel Pathways to Mission Success Command & Data Handling,(C&DH) Lessons Learned	23

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Conduct end-to-end testing - absolutely essential	Integration testing and verification ECLSS	Robyn Gatens	It is important to note that this end to end testing is absolutely critical before we fly future exploration missions. Not only was it the first time in some cases that the flight hardware met the flight software but just everything integrated together is critical before you fly that element.	ISS Video Dashboard Robyn Gatens Clip 2 (all - especially 5:20)	23
"Unexpected things are going to happen"	Design robustness / ECLSS	Robyn Gatens	We learned some things once we launched our ECLSS system to the space station on orbit that we didn't anticipate when we designed it.	ISS Video Dashboard Robyn Gatens Clip 3 (all - esp 2:40)	23
Balance safety v complexity	Safe Design - complexity / ECLSS	Robyn Gatens	So I think as we go forward, yes safety is very critical but we need to find a balance between making something so safe that it is too complex and therefore not as reliable and where is that balance.	Robyn Gatens Clip 5	23

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Leverage technology - employ RFID for inventory control	Operations / Storage	William Robbins	Leverage technology and get the human out of the loop as much as possible .... using RFI de-tags, ... automated readers that are mounted in various places in your living space such that if an item moves you automatically know about it ... (freeing the crew) to operate the vehicle and do science and explore and do those things rather than being an inventory checker.	ISS Video Dashboard William Robbins Clip 8	23
Be weary of obvious answers	Risk Management	Richard Williams	just because a part has been reliable and something that we have used for a very long time here, doesn't necessarily mean that it doesn't have an inherent flaw within it and don't just accept that part the way it is.	KBR 11365- Lunar Reconnaissance Orbiter Project (LRO) - Defect in Socket Contacts (Lessons Learned)	23
Carefully Evaluate Heritage parts with used in extreme thermal environments	Thermal	Charles Baker	The word heritage only applies to thermal if the actual environment that the instrument was used in last was more severe than the environment that it's being base-lined for. If it is less severe than there needs to be resources put in to and early model exchanges and early technical exchanges to help develop the thermal subsystems so that it can handle the more severe environment.	KBR 11377 - LRO Heritage Instruments Still Require Significant Design Efforts (Lessons Learned)	23

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Integrate final hardware together before launch to uncover unplanned problems	MEIT - Component Testing and Verification	Tim Honeycutt	There is no way of understanding all of the scenarios involved with large-scale integration of space hardware until you put the actual hardware together. You can simulate that, you can emulate that to the best that you can but there are some unknowns that you will come across when you actually perform that final integration.	KBR 10440	23
Scale tests to fit the purpose	Test objectives, test cost, testing	Warren Woodworth	The basic guideline is to do the right test and do the test right. Document the test properly and clearly state the objectives and intended purpose of the test. Conducting a test that does more than is necessary or overly complex for the purpose or objective will add increased cost and schedule.	5045 Orbiter Program	23
Plan for success in multiple ways	Parrallel path, mitigation strategies	Lora Bailey	As a project manager I typically always have at least three parallel paths in mind. That is I have a primary path, so that's plan A, and not only do I always have a plan B in my hip pocket but I have a plan C because I want to have at least two layers of redundancies of places to go to in the event that I have a failure with plan A. That's just how I do business and I believe that it the right way to do business, to have at least two backup plans.	KBR 11938 Clip: Context; Parrel path- Time marker: 0:00	23